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The Common Submarine Radio Room

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THESIS

THE COMMON SUBMARINE RADIO ROOM

by

Shawn S. Roderick

June 2011

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THE COMMON SUBMARINE RADIO ROOM

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requirements for the degree of

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ABSTRACT

The CSRR program represents a paradigm shift in the way radio room equipment is procured in the submarine fleet. This program is managed under PEO C4I by SPAWAR PMW 770. This thesis examines the cost, schedule, and performance parameters of the CSRR program itself, not the technology it produces, from the perspective of the end customer, the U.S. Navy, who is both the purchaser and user of this system.

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LIST OF ACRONYMS AND ABBREVIATIONS

AOA	Analysis of Alternatives
C+M	Control and Management Software
C4ISR	Command, Control Communications, Computers, Intelligence, Surveillance and Reconnaissance Intelligence, Surveillance and Reconnaissance
C5I	Command, Control, Communications, Computers, and Combat Systems
CNO	Chief of Naval Operations
CO	Commanding Officer
COTS	Commercial Off-the-Shelf
CPAF	Cost Plus Award Fee Contract
CPFF	Cost Plus Fixed Fee Contract
CRR	Certification Readiness Review
CSRR	Common Submarine Radio Room
DDG	Guided Missile Destroyer
DoD	Department of Defense
EB	Electric Boat Corporation
ECS	External Communications System
EVM	Earned Value Management
FY	Fiscal Year
GFE	Government-Furnished Equipment
GF	Government-Furnished Information
GIG	Global Information Grid
GOTS	Government Off-the-Shelf
IAW	In Accordance With
IBR	Integrated Baseline Review
ICC	Interoperability Certification Committee
I/O	Interoperability
IPCD	Initial Platform Certification Decision
IRR	Integrated Radio Room

IT	Information Technology
KPP	Key Performance Parameter
LA	LOS ANGELES Class Submarine
LM	Lockheed Martin Corporation
MOSA	Modular Open System Architecture
MRTS	Multi-Reconfigurable Training System
NDI	Nondevelopmental Item
NRE	Nonrecurring Expenses
NUWC	Naval Undersea Warfare Center
NWSCTF	Naval Warfare Systems Certification Task Force
OPP	Operating Principles and Procedures
OQE	Objective Quality Evidence
OT	Operational Testing
PCD	Platform Certification Decision
PM	Project Manager
POR	Programs of Record
PPQA	Product Quality Assurance Plan
QRG	Quick Reference Guide
RADM	Rear Admiral
RE	Recurring Expenses
RFP	Request for Proposals
SCN	Shipbuilding and Conversion, Navy
SOS	System of Systems
SSBN	Submersible Ship Ballistic Nuclear
SSC-SD	SPAWAR San Diego
SSC-CH/ SSC-CHSN	SPAWAR Charleston, SC
SSGN	Submersible Ship Guided Missile Nuclear
SYSCOMS	System Commands
TEMP	Test and Evaluation Master Plan
TOC	Total Ownership Cost
TRS	Trouble Reports
VA	VIRGINIA Class Submarine

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I. BACKGROUND

The degree to which a fighting force is able to effectively manage and utilize its communications technologies has a direct impact on mission accomplishment and survivability, both in peacetime and war. In modern war, the importance of communications cannot be understated. In recent years, threats from nonstate actors as well as failing nation states, emerging naval superpowers, and natural disasters, have reinforced the need for timely and accurate communications amongst assets. The new asymmetric and dynamic worldwide threat environment dictates that all Department of Defense (DoD) assets, not just U.S. naval assets, have access to fresh information that impacts their mission. In response to this new environment, the U.S. Navy has begun shifting its warfighting philosophy from one of platform-centric warfare to one of net-centric warfare. The concept of net-centric warfare envisions naval forces as a network of sensors, weapons delivery systems, and decision makers rather than platforms (ships, aircraft, submarines) working semi-autonomously toward a common goal. The net-centric concept flattens hierarchy and increases situational awareness of all connected members, which enables decisions on intelligence that often needs to be acted upon when it is only hours old. The integration of the DoD communications and computer systems into the Global Information Grid (GIG) was the backbone of the Navy's initiative toward using the power of information technology (IT) to increase the agility of combat forces and increase the speed and effectiveness with which the military is deployed while satisfying the need for resiliency and reliability in the face of severe harm.[1]

For submarines, the need to share information in net-centric fashion with naval and joint assets had exposed shortfalls in submarine communications technologies. In the early to mid-1990s, submarine communications suites consisted largely of older, legacy systems that were not designed with net-centric capability in mind, or piecemeal radio suites involving partial integration of new technologies from commercial off-the-shelf (COTS) vendors. As a result, the ability of any given submarine to participate in net-

[1] Lawrence Jones and Fred Thompson, *From Bureaucracy to Hyperarchy in Netcentric and Quick Learning Organizations* (Charlotte, NC: Information Age Publishing, 2007), 242–243.

centric warfare varied considerably. In 1995, the U.S Navy decided it needed a “network-centric communications system designed to support the command and control requirements of the submarine force,” and that this new system would “provide seamless, transparent, secure connectivity for information exchange between submarine users and other Joint, Naval, Department of Defense (DoD), Federal, Allied and Coalition force users of the Global Information Grid (GIG) in support of submarine warfare task areas.”[2] This system was the Common Submarine Radio Room (CSRR).

[2] *Integrated Maritime Communications Systems Mission Need Statement*, 1995, 2.

II. INTRODUCTION

CSRR represents a paradigm shift in the way submarine communications technology is procured, integrated, and managed. CSRR integrates existing program of record (POR) technology with COTS, government-off-the-shelf (GOTS), Nondevelopmental Item (NDI) hardware, and application-specific software through an open architecture approach into a common communications suite for all submarines. The CSRR system functions as a communications gateway, and is interoperable with DoD Command, Control, Communications, Computers and Intelligence (C4I) infrastructure.[3] The goal for CSRR is to leverage existing Navy C4I acquisition programs (PORs) to create a common communications baseline across the submarine fleet, not to develop new technology. Thus, CSRR is a system of systems (SOS). Commonality is attained via standardized user and equipment interfaces, managed by control and management (C+M) software designed for CSRR. Using an open architecture, along with nonproprietary standards/protocols, means that CSRR is able to rapidly respond to changes in equipment needs due to mission or obsolescence issues, yet leverage existing POR investment, which keeps the life cycle cost down.

It is more than the technology itself, however, that makes CSRR stand out as unique. In fact, the way the program was formed, and continues to be implemented and managed, warrants study and, as such, will be the focus of this thesis.

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[3] *Revision 4 of the Test and Evaluation Master Plan (TEMP) for Common Submarine Radio Room (CSRR)*, 2009, I-1.

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III. LITERATURE REVIEW

Much has been written on management of large government projects and defense acquisition systems and, certainly, *general* management principles from these disciplines apply to managing a program like CSRR, but that is where the similarities end. Net-centric programs like CSRR that rely on the program office to integrate existing and new technologies for a need that has no expiration date present special management challenges that have just recently been expounded in print. In their book, *Organizing For a Complex World*, Chao and Ben-Ari write that the management of complex DoD systems has itself become increasingly complex, due to new systems emphasizing net-centric technology, systems of systems (SOS) engineering approaches, and multi-mission configurations.[4] Unlike past Cold War era acquisitions, maintaining a technological edge today means adapting to the rapid pace of technological change in the face of a consolidating industrial base, limited budgets, and more challenging operational environments.[5] The field of information technology (IT) is particularly susceptible to these factors, and adds to them an increasingly blurred demarcation between purely government and purely civilian technology.[6]

Other issues regarding the management of complex systems are the questions of who should manage them, and how they should be managed. Chao and Ben-Ari argue that the federal government's capability and capacity for systems integration has declined over the last two decades, and this has led to shortcomings in management.[7] Table 1 compares capabilities of two types of organizations (government and industry) as they relate to systems integration.[8] According to Chao and Ben-Ari, the government only has an advantage in organizational longevity when compared to industry, and is lacking in traits such as project management skill and technical awareness.

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[4] A. P. Chao and G. Ben-Ari, *Organizing for a Complex World: Developing tomorrow's defense and net-centric systems* (Washington, DC: The CSIS Press, 2009), 31.

[5] Chao and Ben-Ari, *Organizing for a Complex World*, 1.

[6] Ibid., 3.

[7] Ibid., 1.

[8] Ibid., 64.

Table 1. Comparison of Government and Industry Attributes for Systems Integration (From Chao and Ben-Ari, 2009).

Key attributes for systems integrator	**Government**	**Industry**
Technical Awareness	-	+
Project Management Skill	-	+
Customer Understanding	+/-	+
Organizational Longevity	+	-
Manufacturing Expertise	-	+
Organizational Independence	-	-

The perception that industry can better manage an acquisition program than government is sometimes related to the perception of government control being too tight and centralized. With programs like CSRR, which involve rapidly changing technological and mission needs, loose central control can cause interoperability problems, while tight central control slows issue resolution and practically guarantees obsolete systems.[9] Indeed, over the past three decades, the government's performance in public sector management has been criticized as inefficient, ineffective, too costly, overly bureaucratic, overburdened by unnecessary rules, and failing in the provision of either the quantity or quality of services deserved by the taxpayers.[10]

The management of the CSRR program, however, is different from the typical government approach outlined by Chao and Ben-Ari and discussed by Jones and Thompson. The CSRR program office works with program offices from respective PORs to oversee the integration of equipment interfaces, yet they do not have control over the design or manufacture of these PORs; thus, both loose and tight central control exist

9 Chao and Ben-Ari, *Organizing for a Complex World*, 67.

10 Jones and Thompson, *From Bureaucracy to Hyperarchy*, 23.

within the program to facilitate delivery of POR equipment that can immediately be integrated with a CSRR suite. The CSRR team also must possess the technical awareness and customer understanding requisite for presiding over a program that meets all the communications needs of the submarine force, unlike POR offices, which are typically concerned with meeting their individual parameter obligations. CSRR is a heavily government-run program, yet industry participation is retained in those aspects in which it has the greatest cost, schedule, and performance benefits. It is these ways and others in which the CSRR program diverges from traditional acquisition paradigms that make it an interesting subject for analysis.

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IV. A DECISION BETWEEN GOVERNMENT AND INDUSTRY

At the genesis of the CSRR program, procurement of the VIRGINIA class external communications system (ECS) radio rooms had been in progress for five years, headed by a dual industry team of the Lockheed Martin (LM) and Electric Boat (EB) corporations. The VIRGINIA class ECS represented the future direction of submarine force communications, encompassing net-ready components and an architecture that took advantage of government off-the-shelf (GOTS) and commercial off-the-shelf (COTS) technologies. But with all the advances in VA ECS, its primary shortcoming was that it would only be common to the VA platform. The goal for CSRR was to leverage the investment, technology, and methodologies in VIRGINIA ECS to establish a single ECS architecture baseline for all classes of Navy submarines.[11] CSRR would be an open architecture system that integrated existing programs of record (POR) while maximizing use of GOTS/COTS and providing control and management software (C+M) to manage POR physical components to control, process and disseminate Command, Control Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) information.[12]

Leveraging VIRGINIA new construction ECS to provide a baseline ECS fleetwide promised sweeping advantages. First, stovepipe architecture across the fleet would be replaced with common architecture and software/user interfaces. Second, utilizing a modular open system architecture (MOSA) that maximizes the use of GOTS/COTS components would provide design flexibility needed for submarine communications when new requirements emerge or technology becomes obsolete. The use of nonproprietary standards and protocols would allow for more rapid insertion of new technology as it became available; making modernization a “push” system from industry, vs. a “pull” system from government. It was for these reasons, among others, that the U.S. Navy decided to go forward with the CSRR concept.

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[11] SPAWAR, *Common Submarine Radio Room (CSRR) Acquisition Plan (AP)/Acquisition Strategy (AS)*, (2007), 2.

[12] SPAWAR, *CSRR Acquisition Plan*, 1.

A. THE WAY FORWARD

But with whom to go forward with was a key question. LM had already developed C+M software for VIRGINIA and SEAWOLF platforms, and was in position to leverage what it had learned on VIRGINIA ECS. By contrast, the government had decades of in-house expertise with submarine communications and fleet support, to include back-fit integration and modernization.[13] As with any new acquisition program, the decision amongst alternative awards would be weighed by the factors of cost, schedule, and performance. In 2002, there were three options considered:[14]

1. Sole source contract to the VIRGINIA industry team (LM/EB)
2. Open Competition
3. Government team in-house development

The lack of available technical data and schedule for development precluded an open competitive award so, in 2002, the open competition option was shelved with a possible reconsideration for LOS ANGELES class submarines in the future.[15] With the open competition option removed, the only choice to be made was between industry and government, which began with an analysis of how the industry team had been performing on VIRGINIA.

From 1–3 August 2000, an Integrated Baseline Review (IBR) was conducted at Lockheed Martin Naval Electronics & Surveillance Systems-Eagen (LMNE&SS) for the VIRGINIA class ECS program. The IBR team consisted of both government and industry members, and its goal was to gain understanding of the technical scope and time-phased, allocated budget of the work under contracts to support VA ECS. The IBR addressed all industry efforts (LM and EB) associated with major review areas of the component development plan (CDP) of March 1998 but, due to the phased nature of the program, could only address concerns with the first phase. The team uncovered some disturbing findings, including:

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[13] SPAWAR, personal communication, December 2010.

[14] Ibid., and SPAWAR, *CSRR Acquisition Plan*,10.

[15] SPAWAR, personal communication, December 2010.

1. Contractor team cost growth of approximately $1.5 million for the first phase of the program.
2. A budget for logistics efforts that was based on assumptions of deliverables from GOTS/COTS programs that were not part of PORs, and that these deliverables appeared under-budgeted.
3. Potential lack of interoperability with the rest of the Navy and potential further cost growth due to not incorporating all available GOTS PORs with VIRGINIA ECS PORs.

In addition to the IBR, review of a July 2000 LM cost report by SPAWAR showed that LM had moved over $2 million from its program management budget to cover cost growth in other areas, with an implied total cost growth of over $5 million when factoring in scope of work.[16] This finding, along with the IBR results, prompted a recommendation from government to perform an in-depth review of contractor team cost reports and remaining work scope to define future potential cost growth. The full weighing of cost, schedule, and performance risks still needed to be done to adequately compare both options, but it seemed that the government had good reason to suspect the industry-only option would involve risk of cost growth.

During 2002, multiple comparisons of the cost, schedule, and performance risks between the government and industry options were done. The NAVSEA Cost Engineering Team performed an independent assessment of the two alternative approaches for implementing CSRR for SSBN platforms[17] and, in February of 2002, PMW 173 conducted an analysis of alternatives (AOA) for the three original options. Table 2 is the risk mitigation matrix compiled by PMW 173 showing that the government option presented the lowest overall risk, with schedule and cost risks having near equal outcomes, mainly attributable to the government having to redevelop the C+M software.

16 Dan Brothers, *Concern Report*, # Program Management 6, 1.

17 John C. McNellis, “To RADM Phil Davis, USN,” unpublished letter (2002), 1.

	Sole source Contract	**Competitive Contract**	**Government**
Cost Risk (ability to provide CSRR within the current funding)	**High**- EB/LM costs have consistently been higher than the independent Navy estimate	**High**- technical data is not available; can't be a fixed-price contract; include cost to redevelop software	**Moderate/High**- labor costs are significantly lower; include cost to redevelop software
Technical Risk (ability to provide and operationally effective and suitable CSRR for OHIO and LA, with minimial differences from the VA and SEAWOLF variants)	**Moderate**- have access to all the technical data, but have not shown flexibility to accommodate changes (even further definition of GFE equipment has been called a change of scope)	**High**- technical data is not available; starting from ground zero, constrained by another company's architecture	**Moderate**- government involvement in VIRGINIA means not starting at ground zero; good understanding of all the GFE equipment
Schedule Risk (ability to perform per the desired contract schedule I.e, provide CSRR install kits IAW with existing funding)	**High**- EB/LM hasn't been able to meet current schedules	**High**- getting a late start; need to redevelop software from scratch	**High/Moderate**- redevelop software from scratch, but have control software experience, possibly use IRM as basis; gains 10-11 months over other approaches.
Funding Risk (ability to obligate and execute funds IAW the existing funding profile)	**Moderate/High**- sole source would be shorter contracting cycle than competitive, but past EB negotiations have been lengthly	**High**- time required for RFP, proposals, award negotiations will force later start date.	**Low**- can release funding to begin effort months earlier

Table 2. Risk Assessment Matrix (From PMW 173, 2002).

In conjunction with this risk assessment, PMW 173 itemized cost comparisons between the government option and a possible government/industry option to see where the largest cost differences and risks would reside. Table 3 is the cost comparison chart generated by PMW 173 for the SSBN CSRR program.[18]

[18] SPAWAR, personal communication, December 2010.

Table 3. Cost Comparison for the SSBN CSRR Options, (in thousands of dollars) (From PMW 173, 2002).

COST TYPE	EFFORT	ORG	GOV'T ONLY (A)	GOV'T INDUSTRY (B)	DELTA (A-B)
NRE	System Engineering	NUWC	9,423	8,300	1,123
	Software Development	LM	0	4,640	-4,640
		SSC-SD	4,065	1,080	2,985
		LM	0	3,360	-3,360
	Software Convergence	SSC-SD	2,500	0	2,500
	Testing	NUWC	761	761	0
	Alteration Documentation (TRID)	PY/NUWC	2,482	2,482	0
	Program Management and ILS	173/NUWC	2,532	2,927	0
	Certification Facility	NUWC	693	693	0
	Installation Planning	SSC-CHSN	2,095	2,095	0
	Subtotal		24,551	26,338	-1,787
RE	Hardware Procurement	NUWC	38,018	14,306	23,712
	ECSE Procurement and Production	LM	0	43,940	-43,940
	Fabrication and Production	SSC-CH	28,130	25,772	2,358
	Test Witness, Shipping, Receipt Insp.	SSC-CH	0	2,358	-2,358
	Installations	SSC-CH	18,054	17,284	770
	Subtotal		84,202	103,660	-19,458
	Total (NRE+RE)		108,753	129,998	-21,245

Another comparison was done for the SSGN CSRR program, with the column DELTA showing similar differences for categories in direction, although with different magnitudes. There are no fundamental differences between the SSGN cost comparison data and the SSBN data; what follows is a discussion concerning the SSBN data.

There were some cost differences between the government and the government/industry options that are worthy of discussion. Table 3 shows that the government/industry approach would be overall $3.517 million more expensive for systems engineering, yet software development for the two options would be nearly equal in cost. The most notable differences between the two options occur for recurring costs (RE), in which the largest industry contribution was procurement and production of the LM ECSE racks. The differences in cost comparisons between the government and government/industry options are predicated on, among other things, the respective roles that LM and the government would have in developing CSRR for the SSBN platform. Concerns about the ability of either option to mitigate potential high cost and schedule risks were present in statements from either side. The independent assessment by PMW 173 prompted a response from Lockheed Martin's president about the "apparently unknowable basis of estimate for the cost of the SPAWAR/NUWC solution in comparison with the fully justified industry costs put forth by Lockheed Martin."[19] In one instance, LM felt that the $4.6 million estimate for software development was too low, and suggested that LM as the software design agent receive a Cost Plus Fixed Fee (CPFF) contract, with the cost likely being closer to $10 million. But the important differences between the two options went beyond just cost; the overall goal of establishing common hardware and software at minimum cost while maintaining the current SCN funded schedule for SSGN conversion[20] shaped what roles the government and LM would play when contracts would be awarded. As time progressed, and the industry-only option became less attractive, analysis was done for a government/industry option, with LM still playing a chief role in hardware development and design. Below are

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[19] McNellis, "To RADM Davis," 1.

[20] SPAWAR, *CSRR Acquisition Plan*, 9.

brief summaries of each solution, taken from both SPAWAR and LM perspectives, to include advantages, disadvantages, and differences in proposals.

B. THE GOVERNMENT-ONLY OPTION

Because the government would have to redevelop C+M software for CSRR, commonality across VIRGINIA, SEAWOLF, and SSBN/SSGN platforms would be reached on a later timeline. This option would, therefore, present some technical and cost risks with establishing commonality as a backfit to VIRGINIA and SEAWOLF.[21] For hardware, the government option utilized modified Langley racks for COTS equipment, which saved money when compared to the industry option ECSE racks.[22] Costs for systems engineering and labor would be lower due to lower staff-year costs, and this option presented a 10 month schedule advantage due to the ability to immediately begin obligating funds.[23] The schedule advantage was very important in order to avoid disrupting SSBN deployment and availability rotations. Another concern was that CSRR would integrate many existing PORs that were already under the cognizance of the government. CSRR was going to be 80% government-furnished equipment (GFE) or government-furnished information (GFI), so independent of the approach, the liability for providing a large portion of the equipment would reside with the government.[24] Efficiencies with GFI/GFE could therefore be realized with an all-government approach. By comparison, on industry run VIRGINIA/SEAWOLF ECS over 560 GFE/GFI items had to be issued twice by the government; once for VIRGINIA, and once for SEAWOLF.[25] History of the trident IRRs also showed that total ownership costs (TOC) were lowered when utilizing existing government configurations and facilities; the annual cost to maintain a Trident IRR configuration model at LM was $3.5 million, but relocating it to a government facility lowered the annual cost to only $1 million.[26] The

21 SPAWAR, personal communication, December 2010.

22 Ibid.

23 SPAWAR, *CSRR Acquisition Plan,* 10.

24 SPAWAR, personal communication, December 2010.

25 Ibid.

26 Ibid.

last advantage to consider was that the human capital for submarine communications expertise had overwhelmingly resided in the government for decades.

C. THE GOVERNMENT/INDUSTRY OPTION

The government/industry option presented a better technical solution, with both parties concentrating on their respective core competencies. LM would be the software design agent, and the government would control integration, assembly and testing.[27] For costs concerns, LM suggested that the government re-evaluate the use of the Q-70 ECSE racks for use with COTS, in order to leverage development investment and reduce total life cycle cost,[28] while using the in-place Langley racks for GOTS equipment. Leveraging the LM C+M software already developed for VIRGINIA and SEAWOLF would give the fleet an earlier common software baseline, while minimizing the effects on VIRGINIA and SEAWOLF programs.[29] The government/industry approach would, therefore, mitigate some cost and schedule risk by allowing development of the OHIO CSRR in parallel with VIRGINIA and SEAWOLF CSRR.[30] The major disadvantage for the government/industry option was the increased NRE and RE costs due to using LM hardware; SPAWAR predicted additional RE and NRE of over $24 million and $3 million, respectively,[31] for the SSBN/SSGN platforms.

D. THE CONTRACT DECISION

The final decision made by PMW 770 was to use the government/industry option, although in a slightly different form than discussed above. LM was awarded a sole source Cost Plus Award Fee (CPAF) contract, number N00039-03-C-0026, in March of 2003 to develop the OHIO CSRR C+M software.[32] LM was justified as the only responsible source for the work based on their previous VIRGINIA and SEAWOLF software efforts.

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27 SPAWAR, personal communication, December 2010.

28 McNellis. "To RADM Davis," 1.

29 SPAWAR, *CSRR Acquisition Plan*, 6.

30 SPAWAR, *CSRR Acquisition Plan*, 7, and SPAWAR, personal communication, December 2010.

31 SPAWAR, personal communication, December 2010.

32 SPAWAR, *CSRR Acquisition Plan*, 9.

The LM ECSE racks were not to be used to support COTS equipment; instead, modified Langley racks would be used. NUWC NPT would perform the system integration efforts, and SSC-CH would oversee the production efforts.

The government/industry option presented the earliest and best technical solution for the submarine force, saving money through lower government labor costs while gaining a 10 month schedule advantage (by being able to immediately obligate funds and start work), while providing the in-house expertise needed to flex the program as necessary.[33] This solution also allowed CSRR to be fielded on the SSGN platforms without adversely affecting their conversion schedules.

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[33] SPAWAR. *CSRR) Acquisition Plan,* 10.

V. TRAINING: THE MULTI-RECONFIGURABLE TRAINING SYSTEM

A significant advantage of the CSRR program is the development of the Multi-Reconfigurable Training System (MRTS), which enables the fleet to meet greater flexibility requirements for effective communications training, while providing this flexibility at a lower cost per unit than legacy radio room trainers. For years, OHIO class sailors trained on shore using integrated radio room (IRR) trainers. IRR trainers were proprietary, hardware-intensive, expensive to groom (maintain through periodic maintenance), and were not upgraded often. Furthermore, the IRR trainers could only be used for OHIO class crews. LOS ANGELES crews often did not have separate external communications system (ECS) trainers, resulting in training being conducted on shipboard tactical equipment, an evolution often not feasible in port. The lack of available quality training on fast attack submarines contributed to significant deficiencies in submarine communications capability in recent years. The SSBN fleet, on the other hand, had regular training opportunities, but on radio room technology that had not been updated in almost 20 years. The current pace of fleet C4I upgrades can no longer afford a radio room that goes unchanged for two decades.

MRTS gives the fleet the flexibility to fix these issues via a design that utilizes COTS hardware and a common software baseline. A MRTS trainer is a series of flatscreen panels run by control software that can mimic shipboard component interfaces, to include providing high-definition graphic simulations of CSRR system hardware circuit emulation.[34] MRTS can, therefore, be used for operator, maintenance and team training, requiring the student to operate the system as they would at sea while recording every student action for instructor feedback. The control software is common to a baseline, yet provides functionality for loading different variants: the result is a trainer that can run multiple radio room configurations on the same hardware. Unlike IRR, MRTS allows any trainer to be used by OHIO, LOS ANGELES, VIRGINIA, SEAWOLF, and SSGN platforms simply by loading different variant software, which

[34] SPAWAR, personal communication, December 2010.

usually takes only an hour.[35] This allows training commands to schedule an OHIO crew in the morning and a LOS ANGELES crew after lunchtime (for instance), in the same trainer. MRTS has, therefore, both increased available training opportunities for fast attack crews while mitigating schedule demands for regular rotation of SSBN and SSGN prepatrol training periods.

Remarkably, the increase in training flexibility offered by MRTS has also come at reduced costs and with an increased speed of delivery relative to legacy technology. Procuring a baseline hardware trainer for CSRR would cost approximately $22 million per trainer, compared to $500,000 when using COTS hardware components.[36] Maintaining a baseline hardware configuration for MRTS would require expensive grooming and maintenance, and upgrading the baseline would cost between $2 million and $6 million for each trainer.[37] Using COTS hardware allows the common baseline to be managed through software; therefore, the cost of baseline upgrades is lower and can also be spread across multiple sites.[38] Leveraging these cost savings has allowed the Navy to procure eleven MRTS trainers for what two IRR trainers would have cost, with baseline upgrades costing less than $1 million per trainer. This represents a potential cost avoidance of up to $26.5 million per trainer, or $291 million across the entire program, for procurement and initial baseline upgrade.

[35] Personal communication with Bangor Trident Training Facility, September 2010.

[36] SPAWAR, personal communication, December 2010.

[37] Ibid.

[38] Ibid.

VI. RISK MITIGATION AND PROGRAM DESIGN

In 2006, Deputy Secretary of Defense Gordon England and Undersecretary of Defense for Acquisition, Technology, and Logistics Ken Krieg both remarked that the ability of the government to manage rising complexity in weapons and defense systems programs was one of the most important challenges facing the Pentagon.[39] As reported in Ben-Ari and Chao, defense researcher Robert Dietrick has defined "complexity" as it pertains to weapons and other defense systems as "the number of interactions and degree of integration amongst subsystems, as well as the degree of integration at the component level."[40] Dietrick also suggested that increased complexity and, therefore, increased functionality and capability, can adversely affect a program's cost, schedule, and performance outcomes. Popular examples supporting Dietrick's point are the Joint Strike Fighter (JCS), Future Combat System (FCS), and DDG-1000 Zumwalt acquisition programs, each of which has experienced significant cost and/or schedule overruns, and possesses a high degree of technical complexity.[41]

The need for modern systems to have multi-mission and multi-function capabilities, as well as to integrate net-ready technology, has made management of modern acquisition programs correspondingly more complex.[42] This challenge is uniquely acute with SOS programs like CSRR, in which many distinct technologies and systems are linked through a common data network. Most SOS programs have an indefinite lifetime due to a continual need for the capability (like submarine communications), and thus the challenges of integrating new technology with old, managing installation and testing schedules, and ensuring fleet interoperability will never go away[43] for these programs.

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39 Chao and Ben-Ari, *Organizing for a Complex World*, xiii.

40 Ibid., 33.

41 Ibid.

42 Ibid., 31.

43 Ibid., 69.

Despite the obstacles that complex SOS technologies pose to the program manager, however, evidence abounds of successful complex programs delivered on time and on cost. For example, the VIRGINIA class production timeline was able to be shortened despite systems onboard becoming more complex; this contradicts Dietrick's statement, and suggests that negative cost, schedule, and performance outcomes of an acquisition program are independent of the system's complexity. One can reconcile this contradiction by realizing that complexity does not necessarily equal risk, and that managing a system's risk, not a system's complexity, most clearly delineates the respective roles and obligations of technical leadership and government.[44] Government must be comfortable that risks created by complexity are foreseeable, manageable, and acceptable,[45] and put management processes in place to mitigate these risks.

Risk management is done to a certain extent for all acquisition programs but, as stated earlier, more complex systems pose unique challenges that tend to require more rigorous risk management and oversight. It is often organizations with the most robust, clearly defined, and formally documented risk management practices that succeed when others fail, or that sustain the least amount of damage when events outside their control threaten success. It is, therefore, important to analyze risk mitigation practices of complex programs like CSRR to gain lessons learned that can be applied to other complex programs. Risk mitigation is a principle and, therefore, is scalable to the needs of different programs and stakeholders, so the basic tenets derived from comparing and contrasting risk mitigation practices of different programs are worthwhile. It is in this context that risk mitigation in the CSRR program will be compared to results of a task force assessment involving platform and weapons certification in the surface warfare community.

[44] Chao and Ben-Ari, *Organizing for a Complex World*, 15.

[45] Ibid.

A. SURFACE FLEET CERTIFICATION

A 1998 Chief of Naval Operations (CNO) message directed NAVSEA 06 (now NAVSEA 05) to implement a process that coordinates installations and testing of fleet systems' interoperability earlier in the inter-deployment cycle.[46] In 2004, policy and guidance regarding C5I modernization was released by Commander, U.S Fleet Forces Command. In 2005, the Naval Warfare Systems Certification Policy (NWSCP) was written, and since has been the governing document for assessment and certification of warfare systems for U.S. Navy surface warfare platforms. The NWSCP is used by surface fleet leadership to support warfare systems installation decisions and to assess readiness for operational deployment. NWSCP focuses on three major events: the Certification Readiness Review (CRR), the Initial Platform Certification Decision (IPCD), and the Platform Certification Decision (PCD). Of the three, PCD provides the final platform level certification prior to deployment. The PCD is typically conducted after a ships final predeployment maintenance period and after shipboard testing of associated warfare systems. The intent of the PCD is to ensure that no system degradation has occurred between the IPCD and the PCD that will affect operational capabilities. The current NWSCP was intended to be the first phase of a three-phase policy development, but currently no further policy has been promulgated.

In recent years, many surface warfare platforms experienced problems relating to the NWSCP warfare and platform certification process, ranging from the acceptance of degraded combat system capability to delayed deployments.[47] Among these cases was the platform certification of USS STERETT (DDG 104) that occurred in June of 2010.

NAVSEA 05 conducted USS STERETT (DDG 104) platform certification decision (PCD) on 03 June 2010.[48] The purpose of the PCD was to evaluate the DDG 104 baseline, which consisted of 19 POR warfare systems, some of which are common to CSRR. The evaluation covered software, firmware, hardware, documentation, and

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[46] SPAWAR, personal communication, December 2010.

[47] Ibid.

[48] NAVSEA Washington, DC, *USS STERETT (DDG 104) Platform Certification Decision (PCD),* (2010), 2.

training in order to assess the maturity and readiness of the platform for deployment. Although DDG 104 did not fully satisfy all the criteria for the PCD (there are 17 criteria in the NWSCP common to IPCD and PCD), it was certified for deployment with operational considerations/limitations resolved via system level documentation, and 4 fleet advisories in effect. Among the criterion not satisfied were:

Criterion 1: Warfare system computer programs have no unresolved high priority or safety trouble reports (TRS): DDG 104 was certified with four warfare systems not fully meeting this criteria. Issues with these warfare systems were reported "resolved with system level documentation," that is, procedural workarounds and/or documented limitations of the systems were put into place.

Criterion 2: Successfully pass a 25-hour stress and endurance test: The interoperability certification committee (ICC) identified a "significant stability issue" unique to the DDG 104 platform, however certification was granted in part due to the testimony of CO USS STERETT, who indicated that the stability issues were within his ability to operationally manage.

Criterion 6: Further platform interoperability (I/O) testing: DDG 104 was certified for deployment with "C2 capabilities consistent with known documented issues." NAVSEA did remark that the baseline under review was a significant improvement over the old one, and represented the "highest interoperability performance when compared to other platforms in the fleet today." Interoperability issues included degraded ID reliability and engagement issues, and possible degradation of situational awareness and confidence in the automated ID process.

The USS STERETT PCD case is just one that exemplifies fleet stakeholder concerns regarding the certification of surface warfare systems and platforms. Among these concerns is that certification criteria is not rigidly defined, testimony from ships personnel can be used in place of more objective evidence, and that the overall process invokes too much variability, and thus repeatability and uniformity in the fleet suffers. Certain people felt that some factors lead to certifications being "rubber stamped" if systems were not totally broken, due to a lack of funds and time to fix issues prior to

deployment.[49] Other people did not approve of the basic principle of resolving issues by defining limitations through documentation and multiple workarounds, as this knowledge sometimes did not get integrated at the deckplate level.

B. CORRECTIVE ACTION: THE NAVAL WARFARE SYSTEMS CERTIFICATION TASK FORCE

The DDG 104 certification and other events influenced the formation of the Naval Warfare Systems Certification Task Force (NWSCTF) in August of 2010.[50] The task force was headed by RADM Thomas G. Wears, Commander, Naval Undersea Warfare Center (NUWC) with the goal of conducting a coordinated, comprehensive assessment of the state of Naval Warfare Systems certification processes. The task force focused on the following areas (summarized):

1. The process for establishing and resourcing modernization requirements for C5ISR systems.
2. The combat systems certification process, and its effectiveness in supporting follow-on platform certification events.
3. The effectiveness of C5ISR interoperability systems engineering and testing, including evaluation of the PCD timeline.
4. The PCD process to include certification requirements, assessment metrics, risk management practices, fleet involvement, and previous platform certification events which indicated significant issues limiting full or any level of certification for a platform. This category included issues relating to safety and readiness.
5. Manpower as it relates to the conduct of the Warfare Systems Certification Process

[49] SPAWAR, personal communication, December 2010.

[50] Commander, Naval Sea Systems Command. *Establishment of the Naval Warfare Systems Certification Task Force,* (2010), 1.

6. The technical authority structure necessary to support warfare systems certification across SYSCOMS, warfare centers, and program offices.

These categories were divided into five pillars amongst the task force: Combat System Certification, Platform Certification, C5I Modernization and Resourcing, Interoperability, and Technical Authority Structure. The task force Platform Certification Pillar produced 38 major and 15 minor findings, which are grouped into the 13 high-level findings in Table 4. Findings from other pillars significant to this thesis are summarized in Table 5. Many of the high-level findings contained multiple parts, so the brief description/example column in Table 4 reflects the portion of the finding significant to existing CSRR practices.

Table 4. High-Level Findings Summary (From NWSCTF, 2010).

High-Level Finding	**Brief description/example**
Right criteria at warfare system cert level are not clearly identified/articulated	No clear definition of which or how many criteria must be acceptable to determine a no-cert status. Thresholds are debated at certification panels. Other definitions of cert criteria are not clear.
No non-conformance process to allow acceptance of risk by proper authorities	Current practice is debate amongst panel members as to what is "yellow" vs. "red," often without technical authority present. No consistent requirement for documentation/implementation of non-conformance approval process.
Inconsistent defect prioritization and risk standards.	No single source data repository for trouble reports
Timeline for instal/cert events is insufficient for providing decision makers with an off-ramp if there is an issue.	Current policy places certification decision at deployment minus 1 month.
Documentation of capabilities and limitations is inadequate	Integration at the console level is left to the sailor, who must ready many documents, interpret engineering terminology, determine which items are applicable to their jobs, and then remember them, even in stressful situations.
Interoperability evaluations are not conducted early enough to improve the outcome	Testing conducted late in timeline, test sites not sufficiently used to produce results in timely manner.
(Major finding) Existing model permits installations on multiple platforms before OT complete on first platform.	

Table 5. Significant Findings From Other NWSCTF Pillars (From NWSCTF, 2010).

Pillar	Finding	Brief description/example
C5I Modernization	Systems installed that have not completed OT, but were given authorization via LRIP from PEO's.	Problem is exacerbated by insufficient integrated testing during development. Ships have been delivered to the fleet not ready for tasking.
C5I Modernization	There are numerous C5I baselines throughout the fleet.	Causes interoperability concerns, version control concerns, and does not effectively mitigate ILS cost risk.
Combat System	Lack of "right people, right place, right time"	Lack of involvement of appropriate fleet leadership early in the development process. Technical authority representation is not sufficient.
Interoperability	Net-Ready KPP's are insufficient.	Insufficiently detailed, measurable, and testable.

What follows is a line-by-line analysis of these issues as they relate to the CSRR program practices and methods of risk mitigation. To normalize the analysis and, therefore, make the findings as comparable to the CSRR program as possible, findings from the system acceptance test (SAT) phase of the CSRR development, integration, and testing timeline were selected for comparison. Like PCD, SAT "locks in" a baseline that typically remains unchanged until the next baseline is approved. SAT is the third and final test event for a CSRR baseline, which follows Engineering Change Proposal (ECP) development testing and System Design Verification Testing (SDVT). SAT also

performs the function of verifying that the CSRR baseline under test satisfies all lower-level system/subsystem specifications, as well as higher level requirements set forth by the program office.[51] Where applicable to the NWSCTF findings, elements of CSRR SDVT and other program attributes (including the TEMP and CSRR process and product quality assurance plan) will be discussed. The specific SAT used for comparison is for the SSBN 1.1.3.0 baseline report from 27 March 2009.

The Right Criteria at the warfare system certification level are not clearly identified and articulated. This finding deals mainly with the issues of definition and documentation. NWSCTF found that definitions of what constituted an acceptable test criterion, and how many unacceptable criteria could be allowed before the entire certification was unacceptable, were lacking. As a result of unclear definitions, thresholds for pass/fail criteria are debated at certification panels.

The CSRR baseline had to satisfy criteria clearly delineated in six governing documents when undergoing SAT, to include strategic communications parameters, connectivity requirements, KPPs and System Data Exchange Matrix circuit timing requirements, requirements not satisfied during SDVT (if applicable), system level test plans for certain message types, and a stress test plan for target change messages. These documents contain clear definitions of what constitutes a successful test from the individual circuit level to the overall system level. Because CSRR is a system that integrates PORs and legacy systems, testing of CSRR capabilities necessarily incorporates acceptance criteria for its subsystems. The SAT documentation also contains detailed definitions of the pass/fail criteria, which covers everything from the KB size of message to be transmitted, to the quality of data transferred.

There is no nonconformance process to allow acceptance of risk by proper authorities. The current practice is a debate among panel members of standards and thresholds, including what "red" and "yellow" standards should be. A requirement for a nonconformance approval process is not available at the element, combat system, or warfare system level.

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[51] Naval Warfare Center Division Newport, Rhode Island. *CSRR 1.1.3.0 Systems Acceptance Test (SAT) Report, final version*, (2009).

Testing documentation for CSRR baselines contain thorough, unambiguous, and detailed pass/fail criteria for each system, subsystem, and parameter being tested.

The CSRR program is set up in a manner that attacks and resolves nonconformance issues early. The CSRR PM works closely with PMs from respective PORs during the design phase to resolve interoperability issues before any testing takes place. The CSRR Product Quality Assurance Plan (PPQA) is a comprehensive document that is used to delineate the roles and responsibilities of technical authority and project leadership, as well as outline mitigation measures that decrease nonconformity issues at all project stages.[52] Testing of a complete CSRR baseline may begin as early as 19 months prior to the first baseline installation, in order to work out issues early.[53] These are a few examples of entrenched risk mitigation measures that help the CSRR process adapt to changing fleet schedules and needs, and allow quick assessment of technology maturation when these factors rapidly change.

One CSRR example of nonconformance risk being accepted by the proper authorities was the interim fielding decision of the increment 1 version 2 (INC1V2) CSRR kits on SSN 21, SSGN 726, and SSGN 729, which occurred on 24 September 2010.[54] Authorized fielding of these kits had been given pending follow-on operational testing (OT), but the SSGN schedule precluded the OT from happening, and threatened to delay it by almost a year. A delay in the OT for this increment would have postponed delivering the capability for two SEAWOLF and two SSGN platforms by two to three years. Thankfully, the robust and early testing schedule of CSRR baselines and increments provided sufficient evidence to allow fielding this increment without the subsequent OT. The decision was given to the Milestone Decision Authority (MDA), PEO C4I, which concluded that "extensive and successful testing" of the INC1V2 upgrade had been conducted, with results that "substantiate the operational integrity of

[52] SPAWAR, *Common Submarine Radio Room (CSRR) Process and Product Quality Assurance Plan*, 1–1.

[53] SPAWAR, personal communication, December 2010.

[54] Program Executive Officer, Command, Control, Communications, Computers and Intelligence. *Interim Fielding of Common Submarine Radio Room (CSRR) Increment One Version Two (INC1V2) Kits on SSN 21, SSGN 726, and SSGN 729 Acquisition Decision Memorandum,* (2010), 1.

CSRR INC1V2 and minimal risk associated with fielding" prior to the OT. To give an example of what "extensive" is with regard to CSRR testing, the 1.1.3.0 baseline version was able to satisfy 88% of its overall requirements during SDVT, and by the end of SAT had satisfied 98% of its overall requirements. Additionally, no CSRR baseline or increment upgrade is allowed to field with any priority 1 or 2 (significant) problems, and all priority 3 problems require workarounds to be documented at the system level and tracked in a central database.

There are inconsistent defect prioritization and risk standards, and inadequate training related to these risks for those affected parties. Contained within this finding is that there is no single source data repository for trouble reports.

The CSRR program utilizes the CIMS database to generate, track, and modify trouble reports found during testing phases. This is a single integrated database containing all trouble reports that is accessible by all key stakeholders.

The timeline for installation and certification events is insufficient for providing decision makers with an off-ramp if there is an issue. The current policy for the surface fleet places the IPCD at one month prior to availability, and the certification decision at deployment minus one month. This creates schedule risk, as it makes changes difficult to make prior to installation activities beginning. Additionally, technical commands and operational authorities do not consistently share schedule change information, which affects planning, readiness assessment, and certification events.

As stated earlier, system testing for a CSRR baseline can occur up to 19 months prior to the first installation of that baseline. The CSRR PM works closely with fleet operational leadership to coordinate installation and testing of new increments and/or baselines with the availability schedules of submarines such that they will not negatively affect the deployment cycle. Part of being able to mitigate schedule risks with the installation is also the rigorous and comprehensive testing that all CSRR systems undergo. CSRR is unique in that it is the only fleet C4I system that undergoes SOS testing prior to installation; the strength of SOS testing specific to CSRR is that

interoperability and interface issues are able to be fixed in the lab months prior to installation and, therefore, without operational impact to submarine deployment schedules.

SOS testing and knowing availability schedules are just a couple of ways that the CSRR team mitigates schedule risk, the other involves an understanding of what other work is to be performed during these availabilities, so that the CSRR team can identify windows of opportunity to get ahead of schedule and save the Navy money. For the POM 2010 process, the CSRR team outlined an alternative plan for 688 class submarine CSRR integration that would save the Navy time and money.[55] The team realized that 688 class submarines were scheduled to receive ECS upgrades, beginning in FY12, which would incorporate considerable hardware, cabling, and infrastructure changes. Submarines of the 688 class were also scheduled to begin CSRR installations in FYs 15–18, so the initial approach created inefficiencies due to component interfaces needing to be designed/installed twice. Their solution was to accelerate CSRR for 688 class submarines to FY12 in order to align it with component modernization plans; conducting some architecture and infrastructure that would be needed later on for full-blown CSRR, while giving the submarines new ECS capability as originally planned in FY12. Components that were already scheduled to be upgraded would be done in a manner consistent with CSRR requirements in order to avoid duplicate efforts, thus reducing the scope of the final CSRR installation and further mitigating cost and schedule risks.

Documentation of capabilities and limitations is inadequate. Among the concerns expressed in this finding is that there is no single consolidated document that ships' force can reference to understand limitations and workarounds. The operating principles and procedures (OPPs) and quick reference guides (QRGs) are written for specific systems and do not include any workarounds. This leaves integration at the console level to the Sailor, who must reference many documents, interpret engineering terminology, and remember it, even in stressful situations.

[55] SPAWAR, personal communication, December 2010.

With the advent of CSRR came a paradigm shift in the way technical and operational documentation was organized for submarine radio rooms. Troubleshooting and operating procedures are now written at the communications circuit level, not the component level. For instance, the old IRR way of troubleshooting was to consult manuals for the individual components involved in that circuit (like VLF or EHF). These manuals seldom took into account the interface and interoperable nature of components in the radio room, and instead focused in internal hardware or software faults. The new way presents a consolidated and integrated view of the room, where an operator who is having problems transmitting EHF references procedures that include troubleshooting interfaces between subsystem components. Workarounds for CSRR can also be documented this way, as the operations manual reflects operation of the circuits, not the "boxes" that make up the circuits. This defragments operational and technical knowledge for Sailors who do not have time to memorize engineering jargon.

Interoperability evaluations are not conducted early enough in the process to improve the outcome. Currently, interoperability testing is conducted so late in the timeline that it can only effectively be used to characterize limitations to capability, or to provide OQE to not perform the installation or certification for deployment.

CSRR testing for interface management and interoperability is inherent in the testing program, which can occur 19 months prior to installation. Using baseline 1.1.3.0 as an example, lab testing can satisfy 98% of total requirements including interoperability concerns (due to conducting SOS testing) prior to installation. Additionally, integration of a new baseline or block upgrade is not authorized if it potentially could adversely affect submarine deployment schedules.

The existing C5IMP model allows combat systems installations on multiple platforms before combat systems certification, platform certification, or OT are complete on the first platform. This finding represents a concern over the net result of the overall process.

By contrast, CSRR baselines are only installed and tested on one platform before going forward with more installations, and this is the same for block upgrades. The

interim decision to field INC1V2 prior to OT illustrates this point; INC1V2 had been installed on only one SSGN, which was to be the OT platform.

Systems are installed that have not successfully completed OT but were given authorization via LRIP from PEOs. As illustrated from the INC1V2 example, LRIP is not used as justification to install block upgrades to CSRR baselines prior to completion of OT. A comprehensive and robust integration and testing program that satisfies almost all required parameters and interoperability concerns prior to installation was used as justification for installation without follow-on OT.

There are numerous C5I baseline variants throughout the fleet. The finding did not quantify "numerous," but, nevertheless, for operational and cost concerns, there has been a push from top Navy leadership to reduce the number of baselines in the fleet. Instead of naval programs fighting over budgets, top Navy leaders would prefer to fix the inefficiencies in current ship programs to help generate funds for future ships.[56] In 2007, the Navy owned 277 ships but kept 551 different engines in inventory. The Navy also, as of 2007, had 57 submarines but an inventory of over 161 periscopes and masts. The Navy's inventory of components in 2007 also included 7,325 different types of motors, 36,979 types of valves, and 443 categories of generators. VADM Paul Sullivan, head of Naval Sea Systems Command, remarked that this has "been a problem for 20 years." The Navy can no longer afford to keep these kinds of inventories, which are largely held over from Cold War thinking with regard to ship design.

CSRR has only four components that are specific to any given baseline, the workstation, NMT, ADNS INC 3, and crypto equipment. This means that using CSRR, the entire fleet of submarines could be managed with a maximum of 16 baselines, but the goal is to manage the fleet with much less. This is formidable considering that CSRR integrates literally hundreds of subcomponents into a common framework, and that each variant must be (for communication and crypto concerns) capable of communicating with all other variants.

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[56] Sandra I. Erwin, "Future Fleet: Inefficient Shipbuilding Jeopardizes Navy's Expansion Goals," (2007), 1.

Lack of "right people, right place, right time." The lack of involvement of appropriate fleet personnel early in the process leads to relevant issues and requirements not being reflected in the development and certification process of elements.

By contrast, the CSRR PM works early and closely with offices of respective PORs during each stage of development to ensure that relevant issues and requirements are clearly established and/or resolved prior to system integration. The certification process of CSRR as a system involves testing of all subsystem POR interfaces and interoperability concerns.

Net-Ready KPPs are insufficient. The task force found that KPPs were insufficiently detailed, measurable, and testable.

Net-Ready KPPs in the CSRR program are unambiguously detailed in the developmental and testing documentation; this is a result of the CSRR PM office working with POR offices early during the development stages, and via an integrated, robust testing plan that satisfies all subcomponent parameters relevant to CSRR.

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VII. CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

The CSRR program is unique in its design and implementation in many ways that would enable success for any program. The working relationships between program offices, along with comprehensive, thorough risk mitigation practices and robust testing/integration schedules are all solid practices that could be scaled to other acquisition programs. This thesis has analyzed many of the principles, practices, and processes of CSRR from the perspective of the end user, the United States Navy, as they relate to cost, schedule, and performance of the program. Major findings of the thesis are:

1. The CSRR team has risk mitigation, management, and institutional practices in place that appear to address all the major findings in the NWSCTF investigation.

2. The MRTS system has a potential cost savings of $291 million across initial installation and first baseline upgrade when compared to legacy technology. A MRTS trainer allows more flexible training for a greater number of submarine types, at a cost of almost one-sixth of an IRR trainer.

3. The extent of government in-house control over almost all aspects of the CSRR program is nearly total; industry effort is largely regulated to development of software. Government control over the program is centralized to control quality and continuity, yet decentralized to increase speed of delivery and encourage innovation.

With these principles in place, one overarching question remains: Is this program successful, and by what standard of measures? Further research in CSRR should focus on more objective metrics utilized to judge the execution of an acquisition program as it relates to cost, schedule, and performance. Such metrics should include:

1. Analysis of the financial management/budget information for CSRR. Because CSRR integrates many PORs that have separate budgets themselves, financial information regarding CSRR is spread across many

budget and financial documents. This analysis could focus on what the "total" cost of CSRR is to the fleet, as well as standard financial metrics such as meeting budget targets.

2. Analysis of Earned Value Management (EVM) data to ascertain if the CSRR program is meeting purposed schedule demands.

3. Trend analysis of testing different variants and baselines of CSRR technology as they progress over time. Analysis of potential learning curve trends and/or its correspondence with changes in the testing instructions/executions.

4. Analysis of the CSRR model as it would apply to surface ships.

5. Analysis of cost savings with respect to the reduced logistics burden CSRR presents when compared to legacy technology.

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